Advanced Hemodynamic Monitoring
with the Edwards Swan-Ganz Catheter

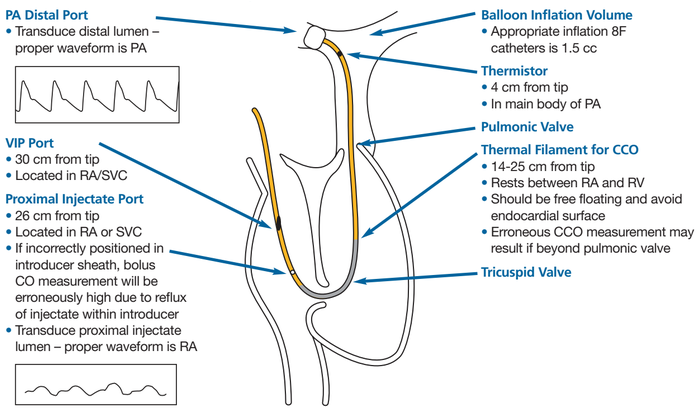
The advanced technology Swan-Ganz catheter, using the same functionality as the standard Swan-Ganz catheter, provides the ability to continuously monitor the balance between oxygen delivery and consumption and investigate the root cause of an imbalance through analysis of the components of stroke volume (preload, afterload, and contractility).

ADVANTAGES OF THE ADVANCED TECHNOLOGY SWAN-GANZ CATHETER AS COMPARED TO THE STANDARD SWAN-GANZ CATHETER

- Maximum amount of diagnostic information with same invasive procedure
- Continuous assessment of DO_2 / VO_2 balance with SvO_2 monitoring
- Continuous assessment of adequacy of CO by assessing DO_2 / VO_2 balance with SvO_2 monitoring
- Continuous assessment of components of stroke volume (preload, afterload, and contractility) (RVEDV, SVR, RVEF and SVI)
- Increased accuracy of cardiac output calculations, elimination of ventilator cycle and thermal noise effect
- Mitigation of:
  - User error in association with wedge procedure/calculation through automated alternative preload parameter (RVEDV)
  - Inappropriate preload assessment secondary to changes in ventricular compliance affecting PAD or PAOP
  - Pulmonary artery rupture potential associated with wedge procedure by providing automated preload parameter (RVEDV)
  - Inappropriate therapy due to miscalculation of PAOP by using automated preload parameter (RVEDV)
  - Iatrogenic infection risk from bolus injections
  - Cardiac output error with CCO automation through elimination of bolus cardiac output user error

CCO CATHETER

Thermodilution Continuous Cardiac Output Catheter



TROUBLESHOOTING CCO AND CCOMBO CATHETERS

Problem/ Displayed Message	Possible Cause	Suggested Action
CCO Measurements Do Not Agree With Bolus CO Measurements	• Catheter position • Instrument configuration • Faulty thermistor or injectate probe connection • Unstable baseline temperature affecting bolus CO measurements	• Verify proper catheter position: - Balloon inflation 1.5 cc - Check for PAOP tracing - Transduce injectate (RA/blue) lumen • Verify that injectate volume and catheter size OR computation constant have been correctly selected • Check injectate probe and catheter connection • Assess factors affecting PA temperature stability: - Rapid bolus infusions - 60 seconds between injections - Shivering - Patient movement - Fighting ventilator
"Check Thermal Filament Position"	• Flow around thermal filament may be reduced	• Verify proper catheter position • Verify free-floating state of catheter
"Warm Injectate" or "Injectate too Warm Check Probe"	• Injectate temperature within 8°C of blood temperature • Injectate temperature >30°C	• Use cooler injectate fluid: - Maintain ice slush solution - If prefilled syringes, remove from cold source and use within 15 seconds • Check injectate probe connection • Replace injectate temperature probe
Loss of Power to Instrument	• Power surge • Power outage	• Press SvO_2 • Press TRANSPORT • Press RECALL *(Note: Calibration data must be less than 24 hours old)*
"SQI = 4"	• Catheter too distal • Low blood flow at catheter tip or catheter tip against vessel wall • Change in Hgb/Hct values • Catheter kinked or damaged	• Verify proper catheter position • Verify patency of catheter • Update Hgb/Hct values using UPDATE function • Check catheter for kinking and recalibrate • Replace catheter if values required and recalibrate • After all above troubleshooting measures are utilized, press OPTICAL RESET
"Red/IR Transmit"	• Optical module contamination/ Optical module damage	• Disconnect catheter from OM • Clean optical connector on catheter and OM • Reconnect. If Error message disappears, do INVIVO calibration • If Error message remains, try different optical module • If Error message remains, change catheter

RVEDV / RVEF

1. Parameters Attained with Vigilance II Monitor

- End-Diastolic Volume (EDV): The volume of blood in the ventricle at the end of the diastole. EDV = SV/EF
  Normal RVEDV: 100-160 mL
  Normal RVEDVI: 60-100 mL/m²
- Ejection Fraction (EF): The percentage of blood ejected from the ventricle each beat

$$EF = \frac{EDV - ESV}{EDV} \text{ or } \frac{SV}{EDV}$$

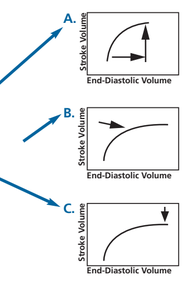
Normal RVEF: 40 – 60%

- Stroke Volume (SV): The volume of blood ejected from the ventricle in each beat
  SV = CO / HR x 1000
  Normal SV: 60 – 100 mL
  Normal SVI: 33 – 47 mL/beat/m²

(Note: As with all measurements in hemodynamic monitoring, the absolute number is not as important as trends and changes in response to therapy)

2. Goal of RV Volumetric Measurements

- Optimize RV efficiency
- Optimize the relationship between EDV and SV
  - **A.** In an efficient state, an increase in preload (EDV) will result in an increase in stroke volume (SV)
  - **B.** Prior to reaching the flat part of the curve, an increase in preload (EDV) will increase SV while not causing a decrease in ejection fraction
  - **C.** On the flat part of the curve, a further increase in preload (EDV) will not result in an increase in SV



At this point, a further increase in volume may:
- Decrease oxygen supply
- Increase oxygen demand
- Decrease left ventricular compliance

Therapy should be directed at increasing contractility or reducing afterload

APPLICATIONS AND CONTRAINDICATIONS

Clinical applications for Swan-Ganz pulmonary artery catheters:

- Intra-abdominal hypertension
- Patients at risk for acute right ventricular dysfunction
- ARDS
- Extensive burns
- Cardiac surgery
- Significant cardiac tamponade
- Significant cardiomyopathy
- Significant constrictive pericarditis
- Drug intoxication
- Severe eclampsia
- Significant intra- or extra-vascular fluid shifts
- At risk for hemorrhage
- Intra- and post-operative high-risk surgery management
- Patient on intra-aortic balloon counterpulsation
- Complex liver resections
- Liver transplantation
- Complex lung resection
- Complex myocardial infarctions
- Pulmonary edema
- Pulmonary embolism
- Pulmonary hypertension
- Acute renal failure
- Severe sepsis
- Presence of or at risk for cardiogenic shock
- Presence of or at risk for distributive shock
- Presence of or at risk for hemorrhagic shock
- Presence of or at risk for obstructive shock
- Shock of unknown etiology
- Shock unresponsive to attempts at resuscitation
- Severe trauma
- Ventilator effects on hemodynamics

Relative contraindications for Swan-Ganz pulmonary artery catheterization:

(There are no absolute contraindications to the use of a pulmonary artery catheter; risk-benefit must be assessed for each patient)

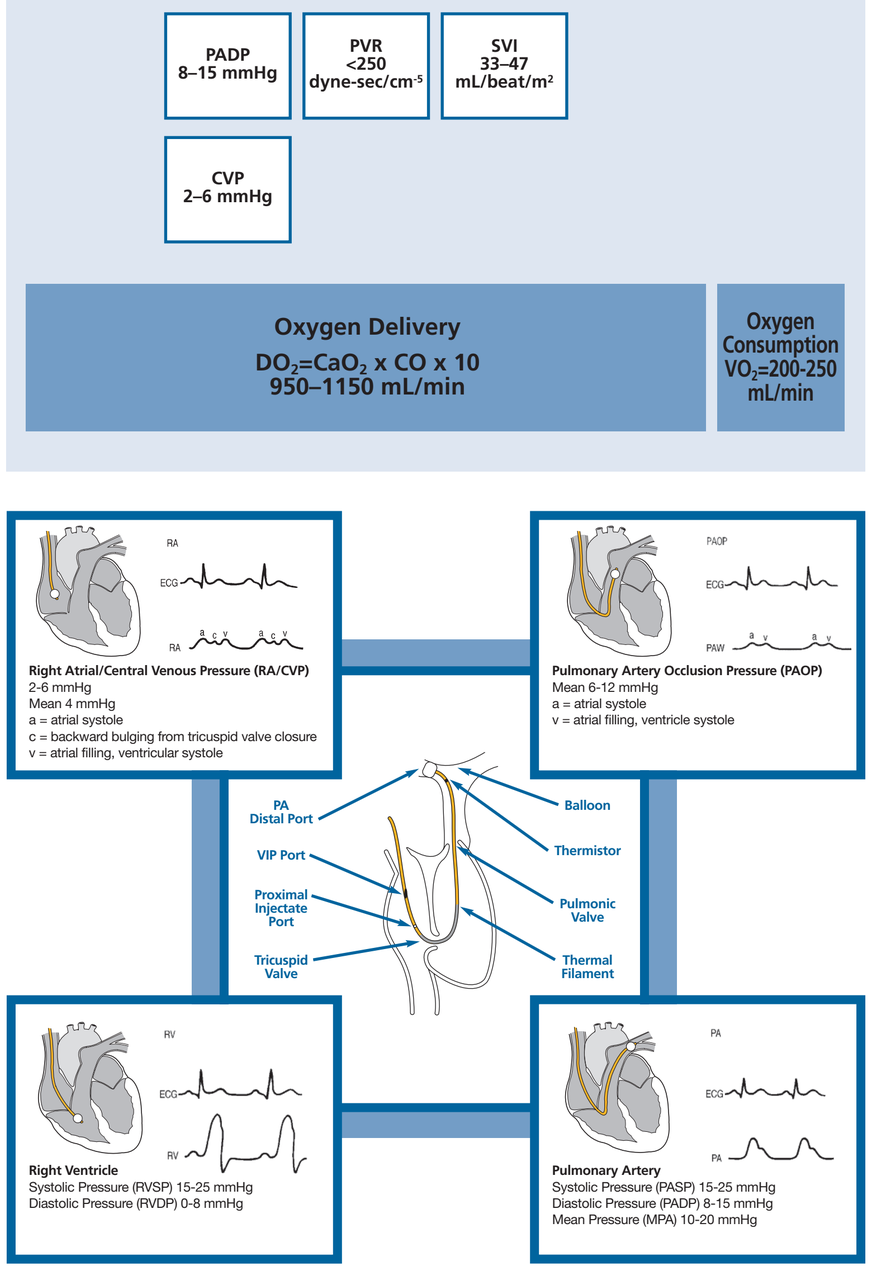
- Left bundle branch block
- Patients with tricuspid or pulmonic heart valve replacements
- Presence of endocardial pacing leads
- Lack of appropriate clinical skills or infrastructure to insert and/or support the use of a pulmonary artery catheter
- Heparin coated catheters in patients with known sensitivity to heparin

CATHETER INSERTION DISTANCE MARKINGS

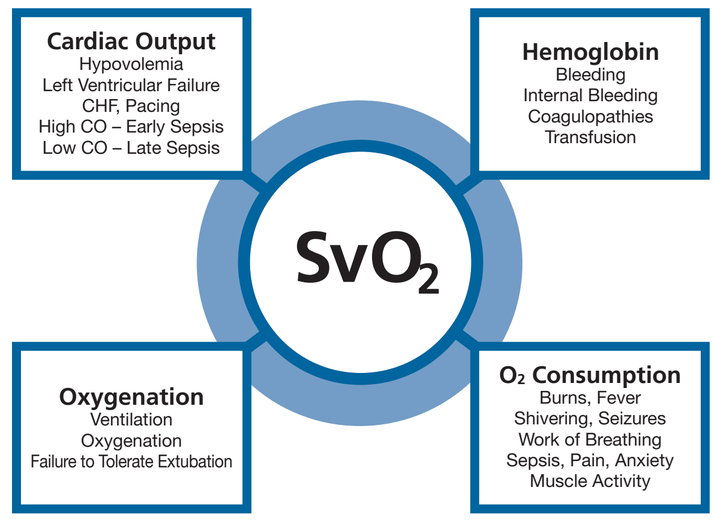
Location	Distance to VC/RA Junction	Distance to PA
Internal Jugular	15-20 cm	40-55 cm
Subclavian Vein	10-15 cm	35-50 cm
Femoral Vein	30 cm	60 cm
Right Antecubital Fossa	40 cm	70 cm
Left Antecubital Fossa	50 cm	80 cm

Note: Catheter markings occur every 10 cms and are denoted by a thin black line. 50 cm markings are denoted by a thick black line. Catheter must exit introducer sheath before inflating balloon.

OXYGEN DELIVERY AND CONSUMPTION

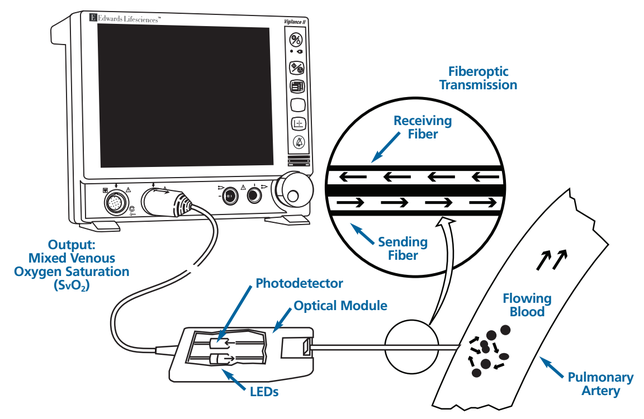


SvO₂



REFLECTION SPECTROPHOTOMETRY

Vigilance II Monitor – Continuous Mixed Venous Oxygen Saturation Monitoring



TROUBLESHOOTING SQI FOR SvO_2 MONITORING

Level	Signal	Description
1	Normal	All aspects of the signal are optimal
2	Intermediate	Indicates a moderately compromised signal
3	Poor	Indicates poor signal quality
4	Unacceptable	Indicates severe problem with one or more aspects of signal quality

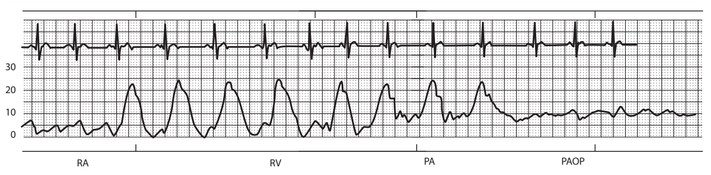
Signal quality may be compromised by:

- Pulsatility (e.g., wedging of catheter tip)
- Signal intensity (e.g., kinking of catheter, blood clot, hemodilution)
- Intermittent wall contact by the catheter

Signal quality may be improved by:

- Update entered hemoglobin and hematocrit values when there is a physiologic change of 6% or greater in hematocrit or of 1.8 g/dL (1.1 mmol/L) or greater in hemoglobin
- Deflate balloon and reposition catheter
- Attempt to distance electrocautery equipment and cables from the Vigilance monitor
- Plug the power cords into separate AC circuits if possible

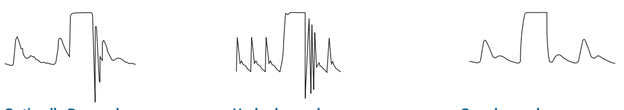
SWAN-GANZ CATHETER INSERTION WAVEFORMS



Tracings noted on insertion. Observe diastolic pressure on insertion as pressures will rise when pulmonary artery reached.

SQUARE WAVE TESTING

1. Activate snap or pull tab on flush device
2. Observe square wave generated on bedside monitor
3. Count oscillations after square wave
4. Observe distance between the oscillations



Optimally Damped:
1 – 2 oscillations before returning to tracing

Values obtained are accurate

- No adjustment in the monitoring system required

Underdamped:
> 2 oscillations

Overestimated systolic pressure, diastolic pressures may be underestimated

- Remove all air bubbles (particularly pinpoint air bubbles) in the fluid system
- Use large-bore, shorter tubing
- Use a damping device

Overdamped:
< 1 1/2 oscillations

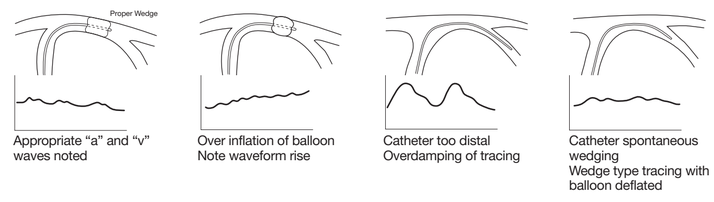
Underestimation of systolic pressures, diastolic may not be affected

- Check for the presence of blood clots, blood left in the catheter following blood sampling, or air bubbles at any point from the catheter tip to the transducer diaphragm and eliminate these as necessary
- Use low compliance (rigid), short (less than 3-4 feet) monitoring tubing
- Connect all line components securely
- Check for kinks in the line

PULMONARY ARTERY PRESSURE MONITORING

The Swan-Ganz catheter and arterial catheter can be attached to a pressure monitoring line. To obtain accuracy, the following should be considered:

- Compliant tubing to accurately transmit patient's pressure waves to the transducer
- Pressurized solution (300 mmHg) to keep disposable pressure transducer patent
- An integral flush device with a restrictor, which limits the flow rate to approximately 3 cc/hour (for adults)
- A flush solution (heparinized or non-heparinized saline – follow institutional protocol for amount of heparin per ml of flush solution)



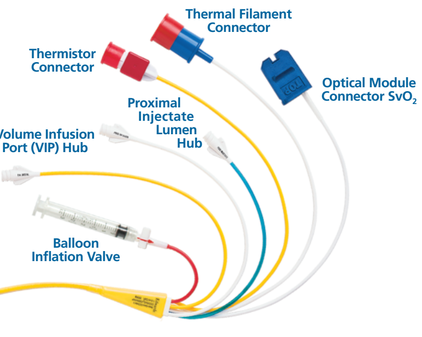
Appropriate "a" and "v" waves noted

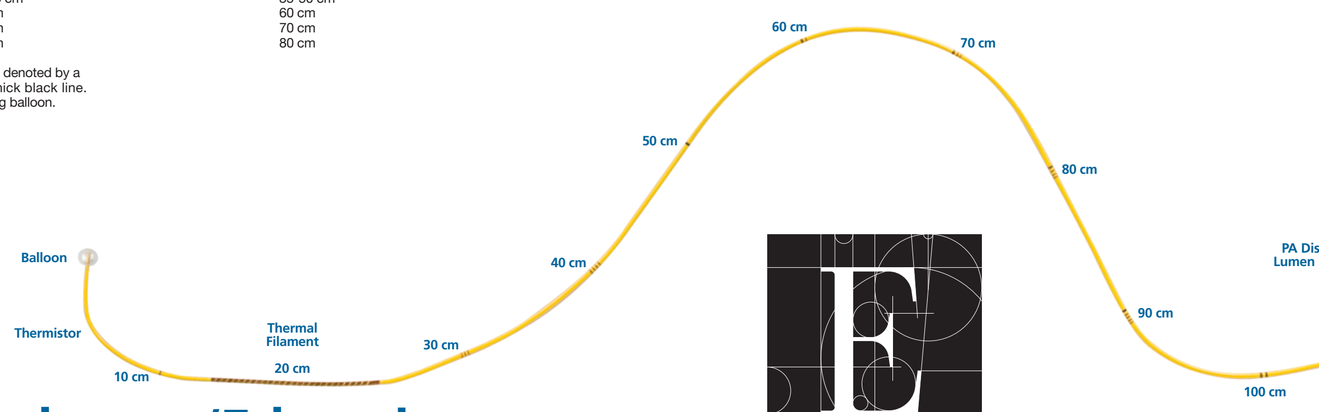
Over inflation of balloon
Note waveform rise

Catheter too distal
Overdamping of tracing

Catheter spontaneous wedging
Wedge type tracing with balloon deflated

SWAN-GANZ CCOMBO V CATHETER





www.Edwards.com/Education

Advancing Critical Care through science-based education since 1972.

Edwards

Editors:

William T. McGee, MD, MHA
Director – ICU Performance Improvement
Critical Care Division – Baystate Medical Center/
Associate Professor of Medicine and Surgery
Tufts University School of Medicine

Jan M. Headley, BS, RN
Director of Clinical Marketing and Professional Education
Edwards Lifesciences, Critical Care – North America

John A. Frazier, BS, RN, RRT
Manager of Clinical Marketing and Education
Edwards Lifesciences, Critical Care – Global

References:

1. Alspach JG (ed.). Core Curriculum for Critical Care Nursing. 6th ed. St. Louis: Saunders Elsevier; 2006.
2. Daily EK, Schroeder JS. Techniques in bedside hemodynamic monitoring. 5th ed. St.Louis: Mosby; 1994.
3. Darovic, GO. Hemodynamic monitoring: invasive and noninvasive clinical application. 3rd ed. Philadelphia: Saunders; 2002.
4. Headley, JM. Invasive Hemodynamic Monitoring: Applying Advanced Technologies.Critical Care Nursing Quarterly. 1998;21:3:73-84.
5. Headley, JM. Puzzled by Continuous Cardiac Output Monitoring? Nursing '97. 1997;32aa - 32dd.
6. Headley, JM. Special Pulmonary Procedures; Continuous Mixed Venous Oxygen Saturation Monitoring. In: Lynn-McHale DJ, Carlson KK. AACN Procedure Manual for Critical Care. 5th Edition. Philadelphia.: W.B. Saunders Company; 2005.
7. Imperial-Perez F, McRae M, Gawlinski A, Keckeisen M, Jesurum J. AACN protocols for practice: Hemodynamic Monitoring. 1998.
8. Leeper B. Monitoring right ventricular volumes: a paradigm shift. AACN Clin Issues. 2003 May; (14):208-19.
9. Mims BC, Toto KH, Luecke LE, Roberts MK, Brock JD, Tyner TE. Critical care skills: a clinical handbook. 2nd ed. St. Louis: Saunders; 2004.
10. Perret C, Tagan D, Feihl F, Marini JJ. The pulmonary artery catheter in critical care. Cambridge: Blackwell Science Inc.; 1996.
11. Pinsky MR, Vincent JL. Let us use the pulmonary artery catheter correctly and only when we need it. Crit Care Med. 2005 May;33(5):1119-22.
12. Thelan LA, Davie JK, Urden LD, Lough ME. Critical care nursing: diagnosis and management. 2nd ed. St. Louis: Mosby; 1994.
13. Vincent JL, Pinsky MR, Sprung CL, Levy M, Marini JJ, Payen D, Rhodes A, Takala J. The pulmonary artery catheter: in medio virtus. Crit Care Med. 2008 Nov;36(11):3093-6.
14. Woods SL, Froelicher ESS, Motzer SU, Bridges EJ. Cardiac nursing. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2005.
15. Zink W, Nöll J, Rauch H, Bauer H, Desimone R, Martin E, Böttiger BW. Continuous assessment of right ventricular ejection fraction: new pulmonary artery catheter versus transoesophageal echocardiography. Anaesthesia. 2004 Nov;59(11):1126-32.

William McGee is a paid consultant of Edwards Lifesciences.

Rx only. See instructions for use for full prescribing information.

Edwards Lifesciences devices placed on the European market meeting the essential requirements referred to in Article 3 of the Medical Device Directive 93/42/EEC bear the CE marking of conformity.

Edwards Lifesciences

Edwards Lifesciences LLC · One Edwards Way · Irvine, CA 92614 USA · 949.250.2500 · 800.424.3278 · www.edwards.com
Edwards Lifesciences (Canada) Inc. · Mississauga, Ontario · Canada L5C 4R3 · 905.566.4220 · 800.268.3993
Edwards Lifesciences Europe · Ch. du Glapin 6 · 1162 Saint-Prex · Switzerland · 41.21.823.4300
Edwards Lifesciences Japan · 2-8 Rokubancho · Chiyoda-ku, Tokyo 102-0085 · Japan · 81.3.5213.5700